Hydroponics:ThePotentialtoenhancesustainablefoodproductioninnon-arableareas

Comment [WU1]: Review should appear in this title.

Abstract

Inthefaceofgrowingglobalpopulationandincreasingpressuresonarableland,thepursuitofsustainablеagriculturepracticeshasneverbeenmorecritical.Asoil lesscultivationmethodthatholdsimmense promise for food production in non-arable regions. Hydroponics represents a paradigm shiftinagriculture,offeringasolutiontothechallengesposedbylimitedlandavailability,soildegradation,and water scarcity. Hydroponics revolutionizes plant cultivation by eliminating the need for soil. Itmaintains a balanced nutrient solution, ensuring stress-free and robust plant growth. When comparedto traditional soil-based agriculture, hydroponics exhibits several advantages. One crucial benefit liesin water conservation. Efficient utilization of water is paramount in crop production, and hydroponicsystems excel in this regard. They outperform open field farming by using water more judiciously. Incontrast, traditional soil farming consumes significantly larger volumes of water. Another advantageis nutrient use efficiency. Hydroponic systems outshine soil-based farming in this aspect, as theymaximize nutrient utilization for plant growth. Hydroponics offers a variety of systems, enhancing itsversatility.Itincludesprecisenutrientmanagement,controllingfactorslikepHandelectricalconductivity. Additionally, irrigation in hydroponics is more precise and efficient. Furthermore,hydroponic systemsare often located indoors,enabling year-round crop cultivation.Favourableclimate conditions and readily available water contribute to accelerated plant growth. In contrast,traditional farming relies on sprawling groundspace, limiting its potential. Hydroponic verticalfarming,acommonpractice,optimizesspacebystackingplantsintraysortowers,allowingforhigher plant densities in smaller areas. In summary, hydroponics offers superior water conservation, nutrientefficiency,diversesystemoptions,andyear-roundcropgrowthpotentialwhencomparedtotraditionalsoil-basedagriculture.

Comment [WU2]: Recast.

Comment [WU3]: This abstract does not give a summary of the work done. It should be reworked.

KeywordsHydroponics,ConservationAgriculture,ProtectedCultivation,MordenAgriculture,IndoorFarming,Soil-less Farming.

Introduction

Thebasisofhydroponicsisplantgrowthwithoutsoilinwhichnutrientsaredirectlydeliveredtothewaterinwhichtheyaregrown.Abalancedmixtureofnutrientsisdissolvedinthewaterfor

healthyplantgrowthwithoutstress.OneofthemostsignificantadvantagesofhydroponicfarmingistheabilitytogrowcropsinnearoptimalconditionsusingControlledEnvironmentAgriculture.**[18]**Becauseofrisingpop

Comment [WU4]: Place appropriately. References should be numbered as they appear. This should be 1 instead of 18. And it should be 1 if it is cited again.

ulationandgrowingindustrializingandurbanization,thelandavailableforcultivationisshrinkingatanalarmingrate.Andfeedingsuchavastpopulationwillbecomeincreasinglychallenginginthecomingyearsso~~Hydroponics~~hydroponicsisthenewtechniqueisintroducingintheagriculturesector.wearenotbecometotallydependentoncultivationofland.Theagriculturalindustry needs to solve the problems of food insecurity and provide high-quality and plentiful food.

Comment [WU5]: Delete

Inthisreviewwecomparedtraditionalagriculture(soilfarming)tohydroponics~~.~~**[38].**

Theprimarybenefitsofhydroponicsincludeadecreaseintheuseofchemicalpesticides,fertilizers,andotherfertilizers,aswellassoillesscultivation.Additionally,theuseoflandismoreefficient,resultinginimproved landsurfacearea, reducedconsumption,and betterwatermanagement.Thesebenefits helpto reduce the environmental impact of hydroponics and make it an attractive crop cultivation option inacontrolledenvironment,althoughthehighoperationalcostsmaylimititsappeal**[18].**Hydroponicsisagreatwaytomakefood,eventhoughit'snotthesameassoilcultivation**[15].**Thisliteraturereviewendeavorstoprovideacomprehensiveoverviewofhydroponicsasasustainablefoodproductionsolution.Itwilldelveintothetechniquesthatunderpinhydroponicsystems,examinetheirenvironmentalandresourceefficiencybenefits.The hydroponiccultivationapproachisflexibleandtherearepotentialenhancementsthatcanbeachievedthroughtheimplementationofsimplifiedmodels;acaseinpointistheproposalmadebyBradleyandMarulanda (Which year?).Theirmodelproposedasimplifiedhydroponiccultivationmodelthatrequired25%ofthelandareausedforlandcultivationtobeusedfor immediate hunger alleviation~~.~~**[6].**By delving into the existing body of knowledge on hydroponics,thisliteraturereviewaimstocontributetoadeeperunderstandingofitspotentialroleinshapingthefutureofsustainablefoodproduction,fosteringresilienceinagriculture,andaddressingtheevolvingneedsof our world.

SignificanceofHydroponics

By providing a variety of benefits to areas where there is no perfect soil for growing crops,h~~H~~ydroponics has an even greater impact on revolutionizing agriculture. The people of these areas areprovided with a source of income through hydroponics. By installing hydroponic units on land notused for farming, it can help to ~~maximise~~maximize its use. It creates opportunities for local people to set upbusinesses and jobs through the adoption of hydroponic facilities in areas where crops are notcultivated.Andalsohelpsinbestutilizationoflandbysetupahydroponicsunitonthenon-agriculturallands. The crops grown in hydroponics are not dependent on external environment a farmer can growdifferent crops in a limited space. It is more effective to combine hydroponics with Aquaponics.

Fishexcretawillfunctionasasourceofnutrientsfortheplant,promotinghealthygrowth.Becauseoftheir superiordevelopmentandintakeofnutrientscapabilities,lettuceandspinacharethemostdesirablespeciesto growin aquacultureand hydroponics systems.

EfficacyofHydroponicsovertraditionalAgriculture:

(a) WaterConservation: Theutilizationofwaterisafundamentalfactorinthesuccessfulcultivationandproductionofcrops.Hydroponicssystems~~utilise~~utilizewatermoreefficientlythanopenfields.Furthermore, the water consumption in soil farming is significantly greater than that of h~~H~~ydroponics.When water is applied to soil, most of the water is lost due to leaching, as it is not absorbed by theplant's roots. Conversely, in h~~H~~ydroponics systems, the plant is grown directly in the nutrient solution,andwatercontinuestoflowthroughthepipes,meaningthatthewaterisnotwastedandcanberecycled andreusedforotherpurposes~~.~~**[44]**.
Thiscultivationoffersahugepotentialapproachthatisindisputableandrangesofadvantagestoenvironmentalbenefitsbecauseofitshigherefficiencyinusingnutritionalandwaterresources**[14,41]**.

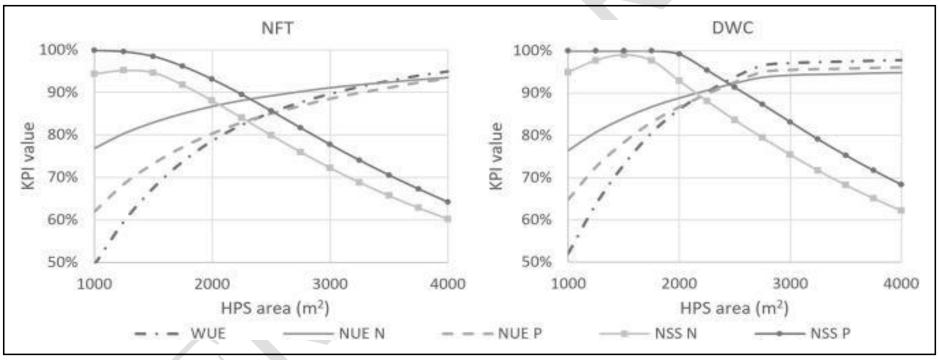

Fig1. Showsthewaterandnutrientuse efficiencyofNFT,&DWCSystem**[48].**

Comment [WU6]: Figure 1 should be mentioned in the previous paragraph before placing it here.

Comment [WU7]: What is the meaning of these abbreviations?

(b) NutrientUseEfficiency

The n~~N~~utrient use efficiency of hydroponics system is much greater than the Soil Farming.Controllingnutritionalsolutionsandtakingdailymeasurementsofliquidnutrientsisessentialinorderto prevent excessive salinization, as well as controlling microbial diseases and pests to prevent anylossof production **[25].**

Table1. NutrientuseEfficiency,inclosedHydroponicssystem~~:~~

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Nutrients	Saving %
Phosphorus(P)	31.4%
Potassium(K)	52.1%
Calcium(Ca)	63.5%
Magnesium(Mg)	47.9%
Sulphur(S), Sulphate (SO4)	49.4%
Chlorine(Cl)	51.9%
Iron(Fe)	50.9%
Zinc(Zn)	47.9%
Manganese(Mn)	24.6%
Copper(Cu)	53.3 %
Boron(B)	47.2 %
Ammonium(NH4+)NO3-	42.1%

Comment [WU8]: Use a proper Table. It should have 3 lines only. See the sample.

Source**[23]**

Nutrients	Savings (%)

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TypesofHydroponicSystems

1. Nutrient film technique the nutrient film method, NFT, is a hydroponic technique in which plantsstandinashallowstreamofwatercontainingallofthedissolvednutrientsnecessaryforthegrowthofplants. This water flows between growing tanks holding plant roots. The roots of plants retrievenutrients, and because the stream is shallow and the roots are floating in the air, the roots may alsoabsorboxygen **[47]**.

ThedrawbacksofanNFTsystemarethatitnecessitatesfullcoverageofallthepipingsystemsthroughwhich the nutrient solution passes. Algae growth becomes dominant even with minimal exposure tosemiopenconditions **[30].**TheNFThydroponictechnique wasdevelopedby **[2]**.

Thismethodinvolvesthecontinuousflowofnutrientwaterfromareservoirintotheplantingmedium,whichis then filteredthrough agutterand distributed throughthe roots of the plants.

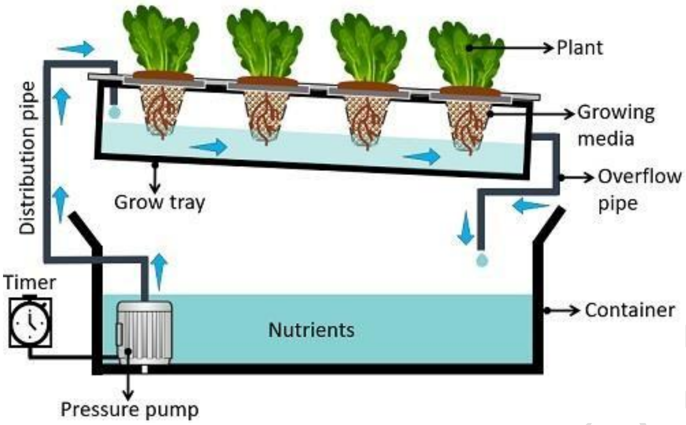


Fig2.Nutrient filmtechnique. Source**[8]**

2. Dynamicrootfloatingtechnique

The Taichung District Agricultural Improvement Station in Taiwan created the DRFT in 1986.Thefertilizersolutionispushedthroughoneendandcirculatedinthechannelsbeforebeingcollectedand returned to the tank reservoir. Instead of the NFT's continuously flowing nutrient solution systemthewaterpumpisconstantlyswitchedonandofftochangethedepthofthewater.Alternatively,thepumpcanruncontinuouslyandadrainagesystemcanbefittedtochangethedepth.The concave panels underneath the floating boards are a characteristic of the DRFT. This additionalspace permits roots known as aero roots to develop above the nutrient solution and so obtain moreoxygen**[47].**

In a DRFT, the air space between the sheet that holds the plants in place and the nutrient solution isleft open. The roots that take up the air above the nutrient solution are called "oxygen roots" and theirmain job is to oxygenate the plants. DRFTs don't use active aeration like hydroponic systems do, sotheydon't needasmuchelectricity fromtheairpump andthat meanslowercosts.**[22,24].**

The DRFT resulted in a 78% decrease in electrical power consumption in comparison to the RAFTplantcultureand a10.3%decreasein totalelectricalpowerconsumptionfor thesystem**[45].**

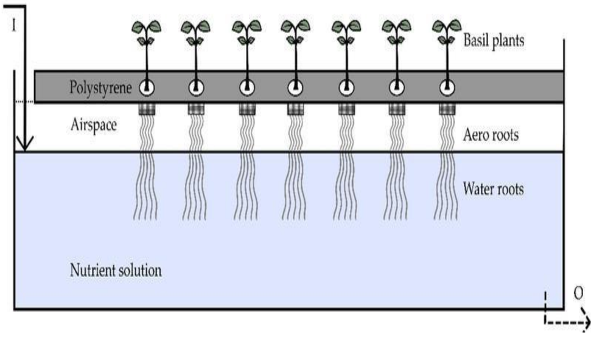
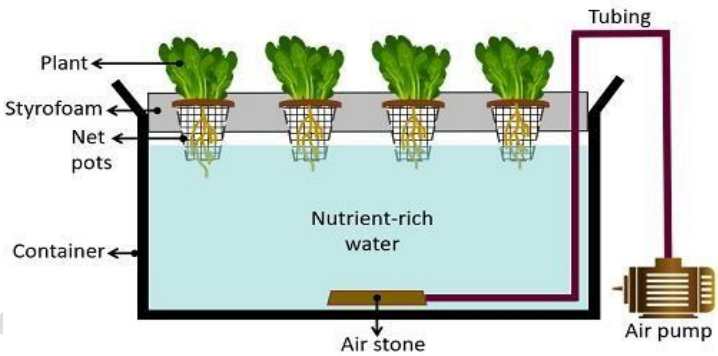


Fig3.DynamicRootFloatingTechnique. Source**[37]**

3. Deepwaterculturetechnique

Thedeep-waterculturesystemistheeasiestsystemtouse.Withthistechnique,knownasDeepWaterCultureOne,younormallydevelopitusingareservoirthathasadecentwaterholdingcapacity.Your fertilizer solution will be less volatile if you add additional water. A plant's roots remainsuspended in a water and fertilizer solution that is well oxygenated in a D W C system **[10].** Thehydroponicallycultivatedlettucecropisthemostabundantintheworld,accountingforapproximately99%ofthehydroponicleaf area, andispricedapproximately40%higherthanconventionallettuceintheDWC



[25].

Fig4.DeepWaterCultureTechnique. Source**[8]**

The DWC system, considered to be one of the most significant hydroponic systems, demonstrated aclearand efficient impact on vegetation growth, with the highest results for vegetative growthcomponentsforboth lettucevarietieswhencomparedto terrestrialfarming systems**[16].**

4. Ebbandflowmethod

The system consists of a grow tray and a reservoir filled with a nutrient solution. A pump isusedtoperiodicallyfloodthegrowtraywiththeNutrientsolutionwhichthendrainsaway**[34].**

Fertilizer and water solutions are diluted gently into pro-trays; frequently, the water pump has a fixedtimerthat will rapidly fill growingbeds at predetermined intervals.

Thesolutionoffertilizerandwatermovesovertheoutletandreturnsbackintothetankwhenitreachesa targeted level. It releases the necessary oxygen for the growth of roots and plants. which results inoxygen and nutrients being supplied to the plants on an ongoing basis by flooding and drainage thatpromotehealthy development**[32].**

Thewateringtimesaretypically20to30mininmostcommercialebbandflowsystems,thesubstrateis capable of taking up at least 90% of the effective water holding capacity **[9].** This is the firstcommercial hydroponics system to operate on the flood and drain principle. The system consists of agrowtrayandareservoirfilledwithanutrientsolution.Apumpisusedtoperiodicallyfloodthegrowtraywitht heNutrientsolution which thendrains away**[34].**

Although a considerable amount of research has been conducted on various aspects of ebb and flowsub-irrigationsystems,**[12].**

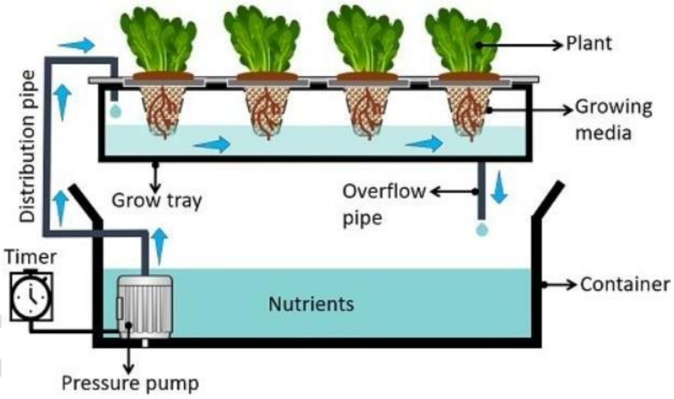


Fig5.Ebband FlowMethod. Source**[8]**

Greenhouse irrigation systems are often praised for their use of Ebb and Flow Sub irrigation Systemsdue to their advantages in terms of energy conservation compared to traditional irrigation techniques**[19].**

(5)Aeroponics

Aeroponicsisaninnovativemethodofcultivatingcropsitisessentiallyanair-watercultivationsystemwheretherootsoftheplanthangdowninsidetheplant.inaclosedcontainerinthedarka nd intheopenairtopassthroughthewater-feedsprinklers.Theupperpartoftheleavesandcrownoftheplantextendsoverthewetarea.Therootandcrownoftheplantareseparatedbyanartificialstructure.

The system uses a nutrient-enriching spray in the air through pressurized nozzles or sprinklers tomaintain hyper growth under controlled conditions **[26].** Aeroponic culture is an optional method ofcultivating plants without soil in growth-limited environments, such as greenhouses **[5].** Aeroponicseed production systems have been developed in response to rising demand for superior, excellent-qualityseed production technologies**[21].**

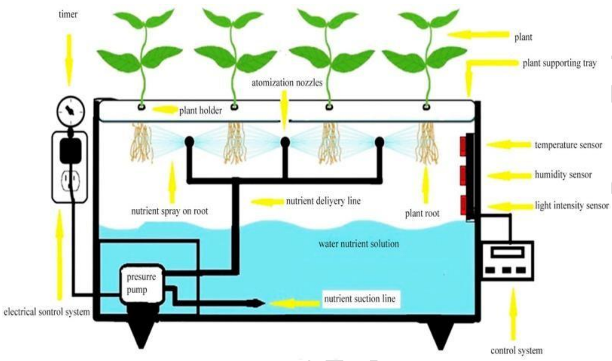


Fig6.Aeroponics system. Source**[26]**

NutrientManagementinHydroponics

Managingnutrientsolutionsiscrucialtoensuringadequateplantnutrition.Toguaranteehealthyplants, fertilizersolutions must beblended witharangeof nutritionalsalts.

pH

AnothercommonparameterinhydroponiccultivationispH.pHisameasureoftherelative concentration of hydrogen ions (H+) to hydroxide ions (OH-). The plant growth is highly affected bythepHvalueofNutrientSolution.BecauseplantscanonlyingestspecificelementswithinaspecifiedpHrange,thepHoftherootzoneeffectivelydictateswhatnutrientsareaccessibletotheplant.Itstatesthat the buffer agents are found very effective in maintaining the pH of the nutrient solution. TheoptimalpHrangehasbeenfound**5-7** asthisistheregionwheremaximumtotalionabsorptionoccurs**[7].**

This study looked at how an automated system was used to control the pH and concentration ofnutrientsin lettuceplants. It wasused to makehydroponic lettuce**[33].**

Fig7.pHBufferSolutions.Source**[16].**

Higher pH values in aquaponic solution may limit the uptake efficiency of certain essential elements,like iron, which is already limited in aquaponic solution **[1].** In order for the plants to be able to takeallnutrientstheyneed;itisnecessarytomaintainapHvalues**[29].**AnydisturbanceinthemagnitudeofNutrientUptakebyplantsinrelationtothebalanceofanionovercationwillaffectthepHofNutrientsolution **[27].**It is generally notadvisable to useapHlower than 5.5

Whencreatingahydroponicnutritionalsolution,certainnutrientdeficienciesandinhibitionofgrowthareoften encountered outsideofthe acceptablerange**[41].**

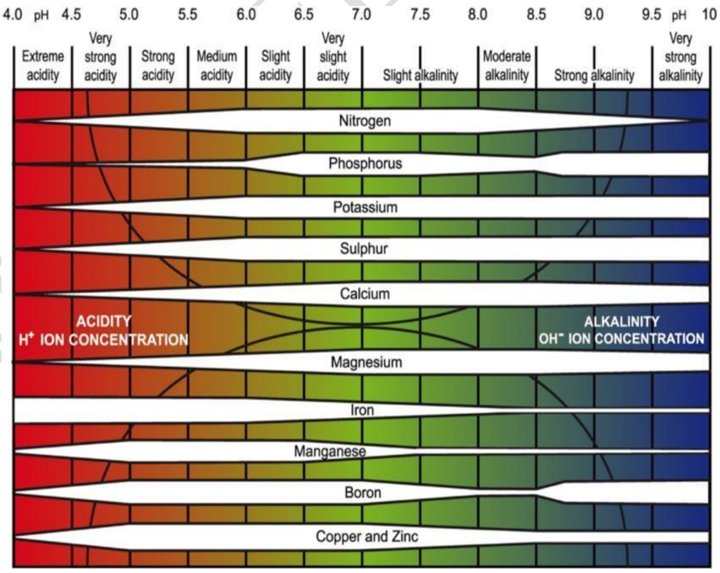


Fig 8. Influence of soil pH on the availability of nutrient elements. The width of the white shadedareasindicates therelativenutrient availability totheplant rootat agivenpHvalue**[51].**

ElectricalConductivity

One of those most critical factors involves maintaining the nutrition solution at the correctrangeofpH&ECvaluesonaconstantbasis.Continuousevaluationandmodificationofthesefactors,often using pH and EC meters, ensures that the crops receive the necessary nutrients without deficitsor toxicity **[39].** Electrical Conductivity (EC) tells us how strong the mineral salts in the nutrientsolution when they dissolved in water. The EC is important to find out the actual concentration of thesaltsinthe Nutrient solution. It'sused to monitor theuseof fertilisers.

The Electrical Conductivity of the nutrient solution is Maintained between **2.6-3.4 mS cm-1. [27]**HigherlevelsofECmayHindersnutrientuptakeduetoanincreaseinosmoticpressures,whilelowerEClevelsmayhaveadetrimentaleffectonplanthealthandyield,asdemonstratedbytheworkof**[40].**

Why EC is Important: Monitoring the EC will give you a better idea of what is really going on inyour nutritional feed. There are three situations arises with EC one time EC remains Unchanged andone time EC goes Down and sometime EC will Higher. These situations will totally dependent on theplantnutrient uptakecapacity.

WhenECremainunchanged(Constant) Thissituationindicatethattheplantnutrientuptakeisequaltotheplant wateruptake.

WhenECgoesDownThisIndicatesthattheplantNutrientuptakeismorethanthewateruptake.

WhenECgoesupThisIndicatesthatthePlantwateruptakeismorethanthenutrientuptake.Tomanagethis situation, you need to dilutethe solution**[52].**

CropSelectionandGrowthinHydroponicSystem:

Table 2.Listofcropsthatcanbegrownoncommerciallevelusingsoil-lessculture.[47].

TypeofCrops	**Crops**

Condiments	*Ocimumbasilicum****(Sweet basil),****Petroselinum crispum***(Parsley),***Origanumvulgare***(Oregano)***Menthaspicata***(Mint)**
Leafyvegetables	*Ipomoeaaquatica****(KangKong)*** *Lactucasativa***(Lettuce),** *Brassicarapasubsp.chinensis***(Pakchoi)**
Medicinalcrops	*Aloevera* **(IndianAloe),** *Solenostemonscutellarioides***(Coleus)**
Vegetables	*Phaseolus vulgaris* ***(Green bean),****Lycopersiconesculentum***(To mato),***Solanummelongena* **(Brinjal),** *Betavulgaris***(Beet),** *Brassica oleracea var. botrytis* **(Cauliflower),***Psophocarpustetragonolobus***(Wingedbean),***Capsicumfrutescens****(Chilli),*** *Capsicumannum***(Bellpepper),***Cucu mis sativus* **(Cucumbers),***Raphanussativus* **(Radish),** *Alliumcepa* **(Onion)** *Brassicaoleraceavar.capitata***(Cabbage),** *Cucumismelo***(Melons),**
Fruits	*Fragariaananassa***(Strawberry)**
Foddercrops	*Axonopuscompressus****(Carpetgrass)****S orghum bicolor* **(Sorghum),***Hordeumvulgare***(Barley),** *Cynodondactylon***(Bermudagrass),** *Medicagosativa***(Alphalfa),**
Cereals	*Oryzasativa***(Rice)**,*Zeamays***(Maize)**
Flower/Ornamentalcrops	*Rosaberberifolia****(Roses),*** *Tagetespatula***(Marigold),** *Chrysanthemumindicum****(Chrysanthemum)*** *Dianthuscaryophyllus***(Carnations)**

IrrigationWaterManagementinHydroponics

The primary rationale for concentrating our efforts on hydroponics is due to the increasingevidence that hydroponics is more sustainable in economic terms than traditional agriculture **[49].** Allhydroponicgrowthtechniquesneedasubstantialquantityofcleanwater.Thebesthomewatersuppliesor agricultural water usually contain compounds and components that can impact either positively ornegativelyonPlantgrowth.Whenitcomestohydroponicbusinesses,fertilizingandirrigationaretwoprocesses that go hand-in-hand. Basically, fertilizers are dissolved into the irrigation water, whileirrigation water is made up of inorganic nutrients **[28].** The growth of plants in hydroponic systems iscontingentupontheavailabilityofwater,nutrients,andoxygen.Thesupplyofwaterandnutrientscanbe regulated through the implementation of an effective irrigation system and the adjustment of theirrigationfrequency.Similarly,thedistributionofoxygen,carbondioxide,andethylenewithintherootzone has been demonstrated to be affected by medium and irrigation growth.**[43].** Generally, theprimary purpose of irrigation is to ensure a sufficient amount of readily accessible free water (highwater potential), to supply essential minerals to the plants, and to enhance oxygen levels in the rootzone**[28]**Theopensystemwasfoundtobethemostwater-efficientofthethreesystemstested,namelyfieldculture, aclosedsystem, andan open hydroponicsubstrate system **[27].**

Table3.Elementswithmaximumlevelofallowableinwaterfor Hydroponicsuse:

Elements	Concentration,mg/L(ppm)
Boron(B)	<1
Calcium(Ca)	<200
Magnesium(Mg)	<60
Chloride(Cl)	<70
Zinc(Zn)	<1
Sodium(Na)	<180
Carbonates(CO_3)	<60

Source[**17]**

TechnologicalAdvancementsandFutureProspects

Hydroponics,asoillessagriculturaltechnique,haswitnessedremarkabletechnologicaladvancements in recent years. This innovative approach to farming has gained popularity due to itspotentialtoovercomevariouschallengesassociatedwithtraditionalsoil-basedagriculture,including waterscarcity,limitedarableland,andclimatechange.Hydroponicspromotesenvironmentalconsciousness in general, and may potentially contribute to environmental sustainability by reducingtypical agricultural contaminants. Foods grown hydroponically tend to have a higher nutritionalcontentandarehealthierthantheiralternatives.Thisenvironmentallyfriendlyformoffoodproduc tionisexpectedtobethepreferredagriculturaltechniqueinthefuturetomeetthegrowingdemandsoftheworld 's population **[48].** Now we are discussing the latest advancements in soilless farming. One ofthe most recent innovations in the field of hydroponic farming is automated growth system. Sensorsin this system continually track and update environmental conditions, The most recent developmentsin greenhouse cultivation have been the result of technological progress and wireless communication**[11].** Such as temperature, Humidity Light pH nutrition level, and other variables. Hydroponics maybe an essential element in the future of exploration in outer space, as no soil has been identified thatcan sustain life in outer space and the transportation of soil through space shuttles appears to beimpracticable **[4,42]** Producer are able to monitor and adapt the environment for plant Developmentusing cultivation technologies and eliminating the need of human involvement. Furthermore, smartnutrient delivers the appropriate balance of nutrients and organic compounds to encourage healthydevelopment withought sacrificing performance to assist with crop management, these equipment'smay be managed remotely and connected with mobile application **[35].** LEDs offer several uniqueadvantagesovertraditionallightingsystemssincetheyarethemostenergy-efficientandenvironmentally friendly lighting technologies currently available **[3].** The advancement of LEDtechnology, with its capacity to pick particular wavelengths, allows for the invention of personalizedlight compositions for manipulating the structure of plants. Plant quality (energy distribution amongvarious wavelength) is frequently a combination of particular plant properties such as branching,compactsize,roots,andtheexpansionofleaves,allofwhicharesubstantiallyimpactedbythespect ralmakeup of LED light **[36].** The low heat output means the light source can be positioned near thecanopy,allowingforaconsistentspectrumdistributionwhileavoidingtissuedamagecausedbyphotostre ss**[31].**Thecarefulselectionofcomponentsofthelightspectrumbyusing LEDlightingtechnologycansignifi cantlyimprovethequality-relatedproperties/characteristicsofornamentalproducts by influencing several physiological and metabolic processes, such as flowering, branching,rooting,pigment biosynthesis, and vaselife**[50].**

Conclusion

Based on the review paper we conclude that the hydroponics has the promising approach toagriculture for sustainable food production in urban areas. The initial investment required to establisha hydroponic system can also be substantial, and the ongoing upkeep of the system can also be achallenge. However more research is needed to be done in Hydroponics to completely understand thepotentialofhydroponicsinurbanareasandmakeitcosteffectivesothatthecostofestablishmentis not become the barrier for small farmers. So, it will become affordable and accessible to small scalefarmers. Hydroponics may be an essential element in the future of exploration in outer space, as nosoil has been identified that can sustain life in outer space and the transportation of soil through spaceshuttlesappears to beimpracticable.

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